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Sustainable Building Specialist

A review of industry feedback and approaches to upgrading to 7-star building fabric – May 2022

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1 Executive summary

Four builders provided the Australian Building Codes Board (ABCB) with examples of buildings with 7-star building fabric which exceeded the upgrade costs predicted by the Consultation Regulation Impact Statement (CRIS) in Melbourne, West Sydney and Perth. These 7-star rating solutions provided by the industry were examined to:

- Compare the methods of upgrading to 7-stars (and associated costs) used in the Consultation RIS (CRIS) with those used by industry to determine whether the CRIS methods were reasonable, and therefore whether they should be used or updated for the Decision Regulation Impact Statement (RIS), and
- If the CRIS methods are appropriate to use in the Decision RIS – determine if there are alternative approaches to the rating solution provided by industry that would enable the industry to reduce these costs.

Software providers of FirstRate5 and BERSPro supplied versions of their software with the updated weather data and star bands that will be used in NCC 2022. Using the updated weather data is critical because 7-star solutions with the current weather data may not apply to the updated weather data.

1.1 Assessment of upgrade costs for houses submitted by the building industry

The ABCB assessed four dwellings submitted by the building industry as examples of plans that showed a significantly higher cost (per square metre) to upgrade to 7-stars than costs modelled for the CRIS. Industry kindly provided both plans and rating files.

The building industry showed higher costs than the RIS forecast with their proposed rating solutions. In part, these higher costs were due to the house size. Two of the houses submitted were more than twice the size of the average house in Australia, as shown in the NatHERS portal.

Larger dwellings have higher costs due to their size and the impact of the area correction embedded in NatHERS. Beyond the size of the dwellings, there were alternative rating solutions to those that would allow costs to be reduced to levels consistent with those found by the RIS for similar houses.

When dwellings provided by the industry were re-optimised to 7-stars using the techniques developed for the CRIS it resulted in estimates similar in cost per m^2 to those found in the RIS (see Table 1 and Table 5). The "RIS techniques" included:

- More nuanced use of high-performance glazing, e.g. using double-glazing with low-coating and argon fill in rooms with the highest heating loads to maximise the benefit. While low-e argon fill double glazing is more expensive, fewer windows need to be double glazed),
- Selected trimming of window sizes, e.g. reducing the width of individual larger windows in living areas by 300 mm. Typically, the reduction in window area varied from 0%-8%. This approach was adopted to ensure that the amenity provided by windows was maintained.
- A more nuanced approach to the use of ceiling fans: using multiple large diameter fans in the largest room(s) with the highest cooling loads.

1.1.1 Other findings observed in the rating checks

- Significant compliance cost savings can be made by using windows that use innovative techniques to reduce heat losses through the aluminium frames, such as mounting the window frame in line with the timber reveal. Two of the larger window manufacturers are already known to use such techniques, and there will be significant competitive pressure on other manufacturers to develop similar innovative methods.

- The dwellings assessed for the RIS, and the examples provided by the building industry had poor window orientation. Significant savings are available through improving dwelling orientation (where possible), so the estimates represent a worst case (see Table 3). Flipping a plan to enhance window orientation can reduce Melbourne's 7-star compliance costs by between $1,000 and $2,000.
- The issues evaluated during the re-rating process raised issues about the extra costs that houses may incur with large windows areas, or which do not reduce window areas at 7-stars. Significant further research was undertaken, as reported in sections 6 to 8.

1.2 The impact of window size on the cost of compliance

1.2.1 Large window areas

The Window: Net Conditioned Floor Area (NCFA[1]) ratio (window ratio hereafter) of the houses modelled to assess costs by the CRIS were, on average, larger than the averages shown in the Australian Housing Data portal ('the portal' see: https://ahd.csiro.au/dashboards/energy-rating/): 18% larger at 6-stars and 25% larger at 7-stars. Consequently, the houses modelled already cover costs for window areas over the average by this amount.

Data from the NatHERS portal was provided to identify the proportion of the housing market that uses window sizes above the average (0.25 window ratio). Dwellings with window ratios of 0.35 have low (3.6%) uptake, so a ratio of 0.30 with 8.6% uptake was selected.

The largest house modelled for the RIS was used for case studies at higher window areas. Because this house is large, it provides an upper limit to the cost of high window areas due to the impact of the area correction. The case studies showed that houses with large window areas do incur higher costs if these window areas are maintained at 7-stars (see sections 6 and 7). Additional costs of between $500 and $6,600 are predicted.

It is easier to reduce window sizes in houses that already have large windows without sacrificing appearance and amenity of the design. On average, reducing the window ratio from 0.30 to 0.27 would allow upgrade costs to return to the values predicted by the modelling used in the CRIS. This window ratio (.027) is still 30% higher than the average window ratio in the portal for 6-star dwellings and 50% higher than the average window ratio for 7-star dwellings. Cheaper options are therefore easily achieved.

While it is economically rational to trim window sizes to achieve 7-stars, not all market segments adopt this strategy. Overall, if homes with large window areas choose to maintain window size when moving to 7-stars, this would add 7.1% to the national total building fabric upgrade cost. This estimate is an upper limit because the large house used for the case study was significantly larger than the average. Consequently, additional costs due to high window areas are unlikely to affect the national benefit cost ratio substantially.

1.2.2 Maintaining 6-star window sizes in 7-star houses

The industry reported concerns that the window area reduction used at 7-stars would underestimate upgrade costs. Each of the typical houses (SBH01 to SBH06 used in the modelling for the CRIS) were re-rated with the window area used to obtain 6-stars. Each dwelling was then optimised to achieve 7-stars with the higher window area, and the costs to achieve 7-stars were derived from the new building specifications.

The additional costs were between 13% (Hobart) and 33% (Brisbane and Mildura). This increase represents an additional cost per square metre of between $0.90 (in Cairns) and $3.69 (in Canberra). See results in Table 16. While these costs are small, they are significant in aggregate . Given the price sensitivity of the

[1] The NCFA is the area of the house measured to the inside walls excluding utility spaces such as bathrooms that are assumed to be unconditioned in NatHERS, expressed as a ratio to 1.

housing market, it is likely that builders/designers would ultimately pursue some level of window trimming to contain costs in poorly oriented houses like those modelled in the RIS.

There is evidence that the market does reduce window areas to meet higher rating levels:

- Data from around 40,000 7-star designs observed in the NatHERS portal shows that when the market voluntarily adopts a higher standard it already responds in this way. The modelling for the RIS only applied half the window area reduction observed in the portal, to ensure a conservative approach was taken
- In Brisbane, a 5-star rating is allowed when an OLA is used with a ceiling fan. The portal shows that the size of windows in 5-star dwellings in Brisbane are larger than the size of windows in 6-star dwellings that do not use the OLA allowance. This demonstrates that smaller windows are used to achieve compliance at higher star ratings within the scope of the current regulations.

Although archetypes were subject to window area reductions this does not mean that all dwellings will need to reduce window areas to achieve 7-stars or face higher costs if they do not. The climatically adapted dwellings case study examples suggest dwelling designs with ideal window orientation used 50% higher window areas and cost between 20% and 60% less to meet a 7-star building fabric standard. Improved design practices to increase the area of well-oriented windows, therefore, offers significantly greater design freedom and lower costs.

As reported in section 3.5, improving window orientation may not need a change to house design because flipping the plan to better suit the lot orientation can lead to significant compliance cost savings. Further, small changes to sales practices, so that dwelling designs are matched with the lots where costs are lower also provides a similar potential to reduce costs.

1.3 Conclusions

Industry feedback suggested that higher costs than those estimated by the CRIS when moving from 6-stars to 7-stars. An examination of the plans and costs provided by industry suggests the difference in results were driven by several factors:

- the house plans provided are much larger than average. This increases the total cost, but cost per square metre were still above those reported in the CRIS;
- focussing (understandably) on the worst orientation, when the costs for more favourable window orientations is much lower;
- a reliance on simple, but higher cost specification changes.

Common approaches for 6-star design improvements are not the lowest cost strategy when used for 7-stars. 7-star requires a more nuanced approach to contain costs. The “RIS techniques” described in section 1.1 significantly lower compliance costs, but will require more time to implement than across the board specification changes.

A central claim was because the houses assessed for the CRIS used dwellings with average window sizes and window size reduction to achieve 7-stars it has underestimated the costs of compliance in significant market segments. The most costs effective approach, to trim windows, was adopted at around half the rate of that found in practice, but it is acknowledged this may not be adopted in all cases. The ABCB conducted a detailed review of these window size assumptions in response to this feedback and this report found:

- Not all houses will need to reduce window area, only poorly oriented dwellings like those modelled for the RIS.
- If window size is not reduced, the portal shows that higher costs predicted would only apply to 8.6% of dwellings across Australia, and the net impact on costs would be small.
- Costs for dwellings with large window areas can be higher, but equally more easily avoided because these dwellings have more opportunity to reduce window area.

When maintaining average 6-star window size at 7-stars in the houses modelled for the RIS the revised cost assessment showed:

- Maintaining the same window size as used at 6-stars do experience higher costs than shown in the CRIS; these costs are small.
- Savings are possible through better design, e.g. developing designs more suited to sites with problem orientation that do not have all living area windows concentrated in the worst orientation, flipping the house on the lot to improve window orientation and enhancing sales practices to ensure that dwelling designs are paired with lots with lower compliance costs;
- in other cases, competitive pressures may mean that significant segments of the industry will adopt window trimming, for poorly oriented houses.

For all these reasons, it is considered that the costs estimated for the building fabric upgrade under the central case remain robust and representative of average costs of the life of the regulation. To ensure costs are contained industry will need to invest time to adapt to the higher building fabric standard to:

- redesign or development of replacement designs for poorly rating dwellings;
- change to dwelling siting practices to facilitate more favourable window orientation;
- improve sales practices to ensure dwelling designs are matched to lots with lower upgrade costs;
- continue professional development for designers and NatHERS assessors to ensure they better understand cost-effective 7-star design optimisation techniques.

2 Introduction

This project checks the 6 to 7-star building fabric upgrade costs developed for the CRIS against examples provided by the building industry.

Four builders provided examples of higher costs than those found in the RIS:

- Builder A: provided 8 house plans at 8 orientations and showed the upgrades required to achieve 7-stars for each dwelling. The houses were all located in Melbourne (NatHERS Climate Zone 60, Tullamarine). FirstRate5 rating files were provided for the 6-star versions of each house.
- Builder B: provided rating file, NatHERS Certificates and cost breakdown for one house in West Sydney. The house only obtained a 5.4-star rating because it was assessed under BASIX. It was upgraded to 6-stars to assess the impact of the NCC proposed stringency improvement. The house was rated in BERSPro, and the BERSPro file was provided.
- Builder C: Provided both BERSPro rating files and NatHERS Certificates for 8 dwellings in Perth.
- Builder D: 3 houses in West Sydney. Rating Certificates only provided. To date, we have not received plans or rating files despite several requests. Rating Certificates show the ratings were prepared using the BERSPro software.

To allow assessment of the ratings in the original software, BERSPro and FirstRate5 were asked to provide versions of their software with the new weather data and star bands. Both agreed, and FirstRate5 provided the software on 02/02/22 and BERSPro on 09/02/22.

Only Builders A to C have been examined for this report because they provided rating files. It is intended to proceed with the rating checks for Builder D when the rating files have been provided.

3 Builder A in Melbourne (Tullamarine)

3.1 What was evaluated?

Two of the dwellings were selected for rerating. Assessing all eight dwellings at eight orientations would not have been possible within the time required. Most of the dwellings Builder A submitted were much larger than the average size shown in the portal. We chose one dwelling close to the average size from the NatHERS portal average of 145.8 NCFA to allow a valid comparison to the average size, used for the CRIS costs: House 2 (145.9 m^2 NCFA), and Builder A requested that House 1 be evaluated (NCFA 386 m^2). The dwelling orientation selected was chosen to represent the worst case, i.e. the most expensive to upgrade.

To compare the approach taken in the RIS with the 7-star upgrade cost evaluation by the builder:

- The cost of the upgrades used by Builder A to achieve 7-stars was costed using the CRIS unit costs,
- Each house was upgraded to 7-stars using the suite of improvement strategies employed during the RIS assessment, and
- The impact of using the windows used in the CRIS evaluation on upgrade costs was compared to the costs of using Builder A's window supplier.

3.2 Summary of findings

Costs are reported below for the two dwellings most similar to the two Builder A houses. The average and range of costs found across the sample of dwellings in Melbourne are also shown.

Table 1 Evaluation of 6 to 7-star upgrade for Builder A houses

Dwelling	Upgrade Cost	Net Conditioned Floor Area	$ / m^2
Average from RIS	$2,058 ($700-$3,800)	167.8	$11.65 ($4.50-$22.00)
SBH01 (largest house from the CRIS)	$3,782	257.6	$13.51
House 1: 7 stars by Builder A	$10,349	386.0	$23.63
House 1: 7 stars using RIS techniques	$7,897	“	$18.03
House 1: 7 stars using RIS windows	$4,257	“	$9.72
SBH05 (house which closely matched the size of House 2)	$1,468	145.9	$10.06
House 2: 7 stars by Builder A	$7,180	145.9	$37.05
House 2: 7 stars using RIS techniques	$3,251	“	$16.77
House 2: 7 stars using RIS windows	$1,999	“	$10.32

3.3 Improvements that were made to Builder A's approach to achieving 7-stars

House 2 and House 1, using the 7-star solutions developed by Builder A on their worst orientation, are significantly more expensive than the two closest dwellings assessed for the CRIS which were also rated at one of their worst orientations.

Some of the rating strategies used by Builder A did not represent the most economical approach to achieving 7-stars, for example:

- Using double glazing without argon fill or low-e coating was found to be significantly more expensive than using higher performance double glazing in the preparatory studies for the RIS. Although lower performance double glazing is cheaper, more windows need to be double glazed.
- Bedrooms have lower heating loads than living areas because cooler temperatures can be tolerated when people are sleeping. Builder A used double glazing in some bedrooms, and this is not cost-effective.
- In a cool climate like Melbourne, ceiling fans do not significantly reduce energy use except in the rooms(s) with the largest cooling loads. Builder A has added ceiling fans to bedrooms, which have small cooling loads because they are cooled overnight and appeared to add only one ceiling fan to large living rooms. In larger rooms, the impact of ceiling fans is much greater when multiple fans with larger diameters are used, and their impact is small when spread across the room area. A more nuanced approach to selecting the rooms, number and diameter of ceiling fans is needed to use ceiling fans cost-effectively in Melbourne.
- While Builder A did not use reflective sarking under the tiles in every orientation, it was used in the poor performing orientation we evaluated. In a cool climate like Melbourne, this improves the rating by around 0.1-stars. The cost is significant, typically over $1,000 for an average-sized house, which doesn't represent good value for money. Further, it is good building practice to sark under a tiled roof as it ensures that a broken tile will not result in roof leaks. Sarking was applied to the 6-star versions of the houses and was not considered to be an energy upgrade but simply good construction practice.
- House A had quite large windows with around 70 m^2 of glazing overall. Some small reductions in window size were applied to contain costs, e.g.
- trimming the width of a very wide window by 300mm, or
- raising the sill height of some full-height windows by 300mm
- Slight area reductions like these do not significantly affect the amenity or aesthetics of the house but can result in significant cost reduction.
- Note that no window area reduction was needed for House 2.

The design strategies described above were used in the CRIS and were applied to the two houses. These strategies resulted in a significant cost reduction for each house. The cost of upgrading to 7-stars was reduced by between 20% and 50%

The improved rating techniques described above should not be seen as a criticism of Builder A or its assessor. The assessors used to develop the 7-star dwellings for this project (Matthew Graham and Tony Isaacs) have extensive experience helping clients achieve 7-stars cost-effectively. In contrast, most assessors and builders aim for the regulatory minimum in the volume market. The dwellings rated for the RIS were rated three times to achieve the final 7-star solution:

- First, for the NatHERS project to develop new star bands, for the current weather data,
- Second as the first cut for this project, and
- Third, after each rating had been costed.

The first attempt was probably similar to the rating improvements that Builder A supplied to the ABCB. Over the past two years, both assessors have been immersed in the task of upgrading dwellings from 6 to 7-stars. With time and a focus on maintaining a competitive market position, any assessors could improve their skills at achieving 7-stars cost-effectively.

3.4 The impact of the window manufacturer on the cost of achieving 7-stars

The windows of the two houses were then changed to use the same suite of windows used in the CRIS evaluation. This was not expected to have a significant impact because MANUFACTURER A is a high-volume window manufacturer whose windows are competitively priced and used by many volume builders. Despite this initial expectation, the use of MANUFACTURER A's windows resulted in a 0.3-0.4-star improvement. The higher performance of MANUFACTURER A windows also allowed the window size reduction to be limited to only 4% compared to the 8% with the current windows.

MANUFACTURER A has an aluminium awning window that is mounted in line with the timber reveal. The timber reveal, therefore, reduces the thermal bridging of the aluminium frame. It is not as effective as a thermally broken frame but achieves a heat loss about halfway between a standard aluminium frame mounted above the timber reveal and a thermally broken frame.

The table below compares the U value (a measure of heat loss in winter) of MANUFACTURER A windows with their biggest competitors. The higher the percentage, the greater the advantage of the MANUFACTURER A windows. The same analysis for sliding windows is shown to demonstrate that it is only the awning window that has this performance advantage.

Table 2 Comparison of the U value (heat loss) of MANUFACTURER A windows with competitors' windows

Manufacturer	Manufacturer's U-value as a percentage of MANUFACTURER A		
MANUFACTURER B**	112%	100%	129%
MANUFACTURER C	109%	103%	129%
MANUFACTURER D	112%	103%	136%
MANUFACTURER E	110%	103%	121%
MANUFACTURER F	112%	102%	129%
MANUFACTURER G	112%	103%	125%
MANUFACTURER H*	114%	102%	132%

* Builder A's window supplier

** MANUFACTURER B is producing their own in-line reveal window, but it is not yet available in NatHERS software. It will be by the time NCC 2022 is introduced. Manufacturer H is also understood to have a similar product in development.

As shown in Table 1, significant cost savings (around 45%) are available to Builder A if they use MANUFACTURER A's windows, another window provider who uses an in-line reveal product, or a manufacturer who uses some other innovative method of improving window performance. It is expected that market competition will help drive innovation using techniques like the in-line reveal to help deliver cost-effective higher performance window products. This innovation may take some time to provide the products needed and involve one-off development costs for window manufacturers.

A further advantage of the MANUFACTURER A's windows is that the manufacturer has had a range of fixed windows assessed through WERS available in NatHERS software. The frame area of fixed windows is less than openable windows because no additional frame is needed for the openable sash. Aluminium frames have a greater heat loss per m^2 than single glazing, so the smaller the frame area, the lower the heat loss. In cool climates, fixed windows will perform significantly better than a window with an openable sash. Many window manufacturers have either not had their fixed window products assessed through WERS, or these products are not available in NatHERS software. Consequently, the cost of achieving higher ratings in cool climates is exaggerated for window manufacturers who do not have ratings for their fixed window products.

3.5 The impact of orientation on the cost of achieving 7-stars

The dwelling orientation with the highest costs was used in the analysis above. Less double glazing was needed when the building was sited at other orientations. Table 3 shows the upgrade costs at eight orientations for House 2 using the windows selected by Builder A.

Table 3 Cost of Upgrades for the House 2 at 8-orientations

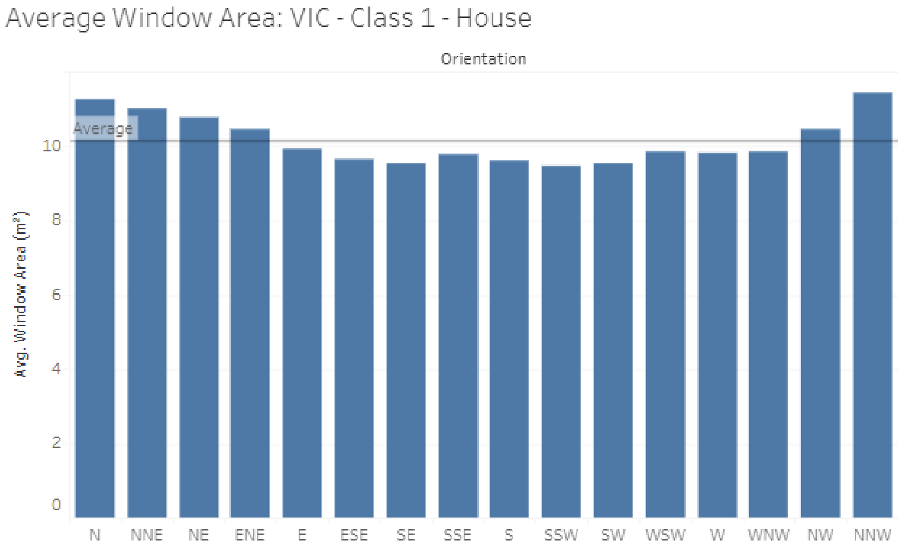
Orientation of main living room windows	6 to 7-star upgrade cost (using Builder A's window supplier)	Upgrade cost as a % of cheapest orientation
West	$2,482.94	299%
North West *	$3,750.96	452%
North	$829.54	100%
North East	$2,576.10	311%
East	$2,920.56	352%
South East	$2,576.10	311%
South	$3,102.96	374%
South West	$3,102.96	374%
Average	$2,667.76	322%
Average per m2	$13.77	

* orientation evaluated in detail above

Table 3 shows that the average upgrade cost across all orientations is significantly lower than the worst orientation. Even without the higher-performing windows used in the CRIS, the average 7-star upgrade cost across all orientations for House 2 is close to the average 7-star upgrade costs reported in the CRIS.

Figure 1 shows the distribution of glazing areas by orientation in Victoria. This distribution indicates that windows are relatively randomly distributed in Victorian Class 1 dwellings. A slightly greater proportion of dwellings use the highest performing north-facing windows than east or west (11.3m^2 compared to 9.9 and 9.8 m^2, respectively). Consequently, the average cost across orientations in the field would be slightly weighted toward the lower cost orientations.

Figure 1 Distribution of Glazing by Orientation in Class 1 dwellings in Victoria



3.6 Conclusion

The 7-star upgrade solutions developed by Builder A's assessor resulted in much higher costs than assumed in the CRIS: \$18 and \$37/m^2 compared to \$12/m^2. To some extent, this is in line with the CRIS because

- these dwellings were assessed on their worst orientation while the CRIS dwellings were oriented on one of the worst orientations, and
- the NatHERS area correction effectively requires a higher level of energy efficiency for very large houses (more than 2.5 times the average from the portal) like House 1. The large house modelled for the CRIS (SBH01) also showed higher upgrade costs than the average due to the impact of the area correction.

By contrast, the CRIS focuses on the central case. That some dwelling sizes and orientations have higher costs than the central case is only to be expected.

Detailed examination of the methods used to obtain 7-stars by Builder A showed several opportunities to reduce these upgrade costs, such as:

- More nuanced use of double glazing: using higher performance glazing and focussing on rooms with the highest heating loads,
- Selected trimming of window sizes for the larger windows (4%-8% in the larger house, not needed in the smaller house),
- A more nuanced approach to the use of ceiling fans: using multiple large diameter fans only in the room(s) with the highest cooling loads.

When assessed with these upgrade techniques – as applied in the CRIS evaluation – costs are significantly reduced and fall within the range of dwellings assessed in Melbourne. This finding suggests that the industry will need time to develop their skills in achieving 7-stars cost-effectively, and more CPD will be required for designers and NatHERS assessors to assist them with this task.

Changing window suppliers to a volume window supplier (with a similar window price) that has higher performance would halve the compliance costs again. This finding suggests that competitive pressures to find lower-cost upgrades will lead to innovation in the residential window industry. However, this innovation can't happen immediately and will involve one-off development costs for manufacturers. It will take time for new products to become available and for volume builder supply contracts to be renewed.

The dwellings assessed were assumed to be sited at their worst orientation. Improved orientation allows upgrade costs to be reduced. When House 2 was evaluated in 8 orientations, the average upgrade cost was similar to the costs found in the CRIS, even without using higher performance window frames.

This evaluation of the two Builder A dwellings suggests that time is required for industry to adapt to the new regulations to allow upgrading of designer and assessor skills and for the development of innovative products to help contain compliance costs.

Even with additional time, dwellings at their worst orientation may experience higher costs. Developing alternative house designs better suited to these orientations may help overcome this issue. Builder A's single storey house compliance costs varied from $840 to $3,750 in Melbourne. Simply flipping the plan to avoid a southern orientation would save around $2,000. On the most expensive North-West orientation, flipping the plan to face South-East would save about $1,000. Flipping plans is not always possible due to the crossover location or where views in a specific - but less favourable - orientation need to be captured to sell the design. More careful placement of crossovers in subdivision planning would also assist the reduction of 7-star compliance costs.

While the initial costs were much higher than the CRIS, the application of more nuanced rating techniques can significantly reduce upgrade costs. The findings from examining the ratings from Builder A does not change the central case modelled by the CRIS.

4 Builder B in West Sydney

4.1 Introduction

Builder B provided one example of upgrade costs from 5.4 stars to 7 stars for one house in Western Sydney (NatHERS Climate zone 28). The rating file was provided (BERSPro), and the upgrades were costed by Builder B. They found costs of around $22,500 to upgrade from 5.4 stars (minimum requirement using BASIX) to 7-stars. Upgrade costs in Western Sydney for a 6-star to a 7-star rating for similar two-storey houses were $2,443 (SBH01) and $2,811 (SBH03).

4.2 Comparison with CRIS unit costs

Table 4 compares the cost of upgrades Builder B listed as required for the upgrade from 5.4 to 7-stars with the same upgrades costed using the RIS cost rates. While insulation costs are similar, the cost of window upgrades and ceiling fans are significantly higher. Note that the Builder B window costs are for supply only, while the RIS costs include installation.

Table 4 Cost of upgrades comparing Builder B and RIS unit costs for upgrading from 5.4 to 7 stars

Item	ABCB RIS Costs	Builder B Costs
Ceiling R from 4 to 6 per m^2	$4.46	$5.00
Wall R from 2.0 to 2.5 per m^2	$3.29	$2.65
R2.0 in walls of wet areas per m^2	$6.40	$4.35
5.4 star window cost*	$17,216.95	$7,786.50
7.0-star window cost	$29,183.01	$22,457.60
Window Upgrade Cost	$11,966.06	$14,671.10
Ceiling Fan cost	$1,680.00	$3,500.00
Total Upgrades	$15,369.23	$22,457.60

* Builder B costs did not include installation, so only the difference between costs and not the absolute costs is relevant. *The cost comparison is for all single glazing at 5.4-stars and all windows double glazed at 7.0-stars to test the unit cost rates. In reality, some double glazing was required at 5.4 stars, and some single glazing was allowed at 7-stars.*

4.2.1 Ceiling fans

While the ceiling fans are a minor part of the difference, it is worth examining the cost difference. The cost of $500 per ceiling fan assumed by Builder B represents a very high-end product, even with the builder's markup. The retail price for a typical 1200mm ceiling fan is less than $160, and some are priced as low as $70. The CRIS assumed $240 installed. The CRIS price is a realistic price.

4.2.2 Windows

The cost differential between the CRIS unit costs for windows and Builder B's quote from their window Manufacturer is greater than the CRIS unit costs would suggest. Either the CRIS unit costs are underestimated, or the costs assumed by Builder B are too high. There is some evidence that the prices quoted by Builder B may be too high:

- Examination of the types of windows contained in Builder B's quote reveals that the low e coating assumed is a very high-performance coating: LightBridge. The coating assumed by the CRIS is Energy Advantage, which is significantly cheaper than LightBridge,

- While the quote provided included windows with LightBridge low e coatings, in optimising to the 7-stars, the much cheaper Energy Advantage low-e coating was all that was required. Further, a significant area of windows (14 m^2) did not need to be double glazed.
- The Builder B 7-star solution assumes around half of the double-glazed windows are air-filled with no low e coating. It is cheaper overall to use argon fill and low-e coatings because, even though they are more expensive, fewer windows need to be double glazed.
- It is unclear whether the quote is a one-off or priced at a volume supply rate. If it is a one-off quote, a volume contract for the supply of the windows may lead to significant cost reductions.

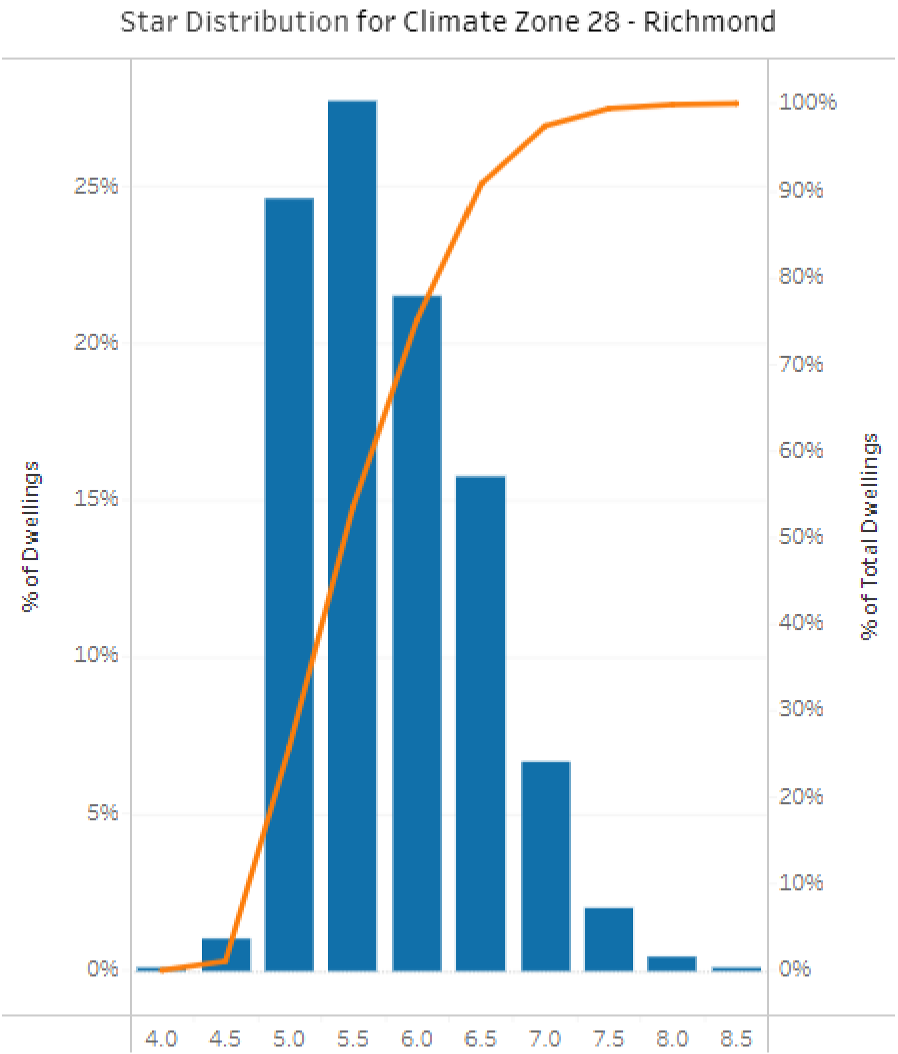
Despite this analysis, it may still be that the cost quoted by Builder B for windows slightly exceeds the assumed costs for the CRIS. The costs developed for the CRIS were based on supplier quotes for a medium-sized supply contract, were supported by AGWA and were checked by a Quantity Surveyor. Consequently, the unit costs developed for the CRIS appear to be robust. If the Builder B costs are higher than the CRIS costs, it may simply indicate the variation in the costs of windows in the field.

What is clear is that a similar dwelling evaluated for the CRIS (SBH01), which has around the same NCFA as the Builder B home, achieved 7-stars with much less double-glazing: 5.3 m^2 compared to 60.9m^2. Regardless of the unit cost variation, using more nuanced 7-star rating techniques will diminish the importance of variability in the cost of double glazing.

4.3 Summary of findings

The initial rating of the Builder B house was 5.4 stars because BASIX does not require a star rating minimum but compliance with maximum heating and cooling loads (BASIX caps). Figure 2 shows the distribution of ratings in the Western Sydney climate over the past 12 months. At 5.4 stars, the Builder B rating is at the lower end of BASIX compliant ratings (the 5.0 column includes 5.0 to 5.4 stars). Some 70% of ratings in Western Sydney achieve a higher performance level.

Figure 2 Distribution of NatHERS Star ratings in Western Sydney over the past 12 months



The CRIS has evaluated the building fabric upgrade cost for improving fabric from 6.0 to 7.0-stars because this is what the NCC requires. However, the industry in NSW will be accustomed to a slightly lower overall stringency than the current NCC. To address this issue, Table 5 shows the cost of upgrading building fabric from 5.4 stars to 6.0-stars without altering window area and the cost of upgrading from 6 to 7 stars.

Table 5 Evaluation of 6 to 7-star upgrade for Builder B house

Dwelling	Total Cost	Net Conditioned Floor Area	Cost / m^2
Average from RIS	$1,891 ($700-$5,400)	167.8	$11.65 ($4.00-$29.00)
SBH01	$2,443	257.6	$8.73
SBH03	$2,811	167.0	$15.05
House: 5.4 to 7 stars using Builder B costs and upgrades	$22,458	222.5	$100.93
House: 5.4 to 7 stars using CRIS costs	$12,127	"	$54.50
House: 5.4 to 6 stars using CRIS costs and upgrade technique**	$5,582	"	$20.15
House: 6 to 7 stars using CRIS costs and upgrade technique*	$2,942	"	$10.62
House: 6 to 7 stars using CRIS costs and upgrade technique and MANUFACTURER A windows*	$2,251	"	$8.13

* window area reduced from a window ratio of 28.1% to 24.9% (a 12% reduction).

** increasing the star rating from 5.4 to 6.0-stars could be achieved more economically if the window areas were trimmed; however, windows were left at the same size for this step.

The final step from 6 to 7-stars, using the CRIS costs and rating techniques, is within the range that the CRIS predicts; however, as shown in section 4.2, Builder B reports higher unit costs for windows than the CRIS assumed.

4.4 Application of CRIS rating techniques to the Builder B plan

4.4.1 The Builder B house has a large window area compared to average

Builder B has a much greater window ratio than the equivalent dwelling assessed for the CRIS: 28.1% at 5.4 stars, compared to 20.1% at 6-stars for SBH01. The SBH01 window area was based on the averages from the NatHERS portal, which shows an average window ratio of 20.9%. The lower window ratio of 20.1% was used for the SBH01 in the CRIS because larger dwellings will have lower ratios. It is still double the minimum size required by the NCC for light and ventilation.

Table 6 shows the distribution of window ratios found in the NatHERS portal for Class 1 dwellings in Western Sydney. The table shows that, at 6-stars, only around 5% of dwellings would have a window ratio larger than observed in Builder B's house. Many dwellings using larger window ratios may have achieved this higher area because of more favourable window orientation, and the builder's house does not have this advantage.

Table 6 Window ratio for 6-star Class 1 dwellings in Western Sydney

Window ratio	Percentage of dwellings
<0.2	35.80%
0.20 -0.24	43.86%
0.25 - 0.29	15.93%
> 0.30	4.43%

At the high window ratio used by Builder B, particularly with the living areas facing south or shaded by an alfresco area, Builder B will inevitably require a high area of double-glazing area. The SBH03 – a smaller three-bedroom, two-storey house - has a window ratio of 32.3%. The north-facing windows in the living areas made this larger area possible. North facing windows help reduce heating loads and do not add to cooling loads by as much as East or West facing windows. While SBH03 did not need double glazing to achieve 7-stars, it did need 22 m^2 of single low-e windows and did have a higher upgrade cost than SBH01. The SBH03 upgrade cost was $2,811 compared to the SBH01 cost of $2,443, despite being 60$m^2$ smaller.

Builder B's house raises the question of how the industry will adapt to increased building fabric stringency. The modelling for the central case of the CRIS assumes that the industry will respond by slight reductions to window areas to save costs, as shown in the NatHERS portal in almost every climate zone. It is difficult to predict how the market will react; some portions of the market may continue to try and build houses with higher window areas. In the Sydney market, where they have achieved compliance under BASIX with a rating of 5.4 stars or lower, this could be a particular issue. A portion of the market may incur higher upgrade costs as a result. This issue is explored further in Appendix A.

4.4.2 Upgrade from 6-stars to 7-stars

6-star upgrades

The Builder B house only achieved 5.4 stars because this was allowed under BASIX. To properly compare the CRIS costs with Builder B's costs, the dwelling needs to be improved to 6-stars. The following modifications were made to achieve 6-stars:

- Double Glaze the following windows clear air-fill double glazing assumed at 6-stars):
- All Kitchen/Leisure/Dining windows
- Upper and lower Lounge windows
- Upper Stair and Office windows
- Add R2.0 insulation between all conditioned and unconditioned zones walls (Garage walls were already insulated), and
- Add 3 x 1200mm ceiling fan to Kitchen/Living and 1 x 1200mm to both Lounge rooms.

7-star upgrades

Modifications needed to achieve 7-stars

- R6.0 ceiling insulation
- R2.5 wall insulation
- Upgrade double glazed clear air-fill windows to argon fill low-e (Energy Advantage) windows
- Increase the diameter of ceiling fans to 1400 mm
- Reduce window sizes:
- 2300 high windows in kitchen Living room, reduced to 2100,
- Reduce the width of windows in daytime zones over 1800 mm width by 300 mm,
- This allowed the windows in the upper Lounge and Office windows to be single glazed

The upgrade cost using the CRIS unit costs is $2,942.

The upgrade cost can be further reduced to $2,251 if the house uses the same window manufacturer as was assumed for the CRIS. The difference is not as significant as it was in Melbourne because heating loads are not as high, and this house has a much greater use of sliding windows than awning windows.

4.5 Conclusion

The rerating of Builder B's house showed that much lower-cost options are available than the initial rating solution provided by Builder B. Less than half the windows needed to be double-glazed using the RIS techniques, and further savings are possible if higher performance volume manufacturer windows are used. The window area of the house with trimmed window sizes was still greater than the average in Western Sydney at 6-stars and significantly higher than the area of 7-stars (See Appendix A).

The upgrade from 6 to 7-stars using these more nuanced rating upgrade techniques is only $2,942, or $2,251 if alternative low-cost windows with higher performance values are used (assuming RIS unit costs). These costs are within the range of costs found by the RIS.

Builder B's unit costs for high-performance windows are higher than assumed in the CRIS. Regardless of questions over the unit cost rate for double glazing or the large window area, applying the RIS techniques to achieve 7-star building fabric significantly reduces the need for double glazing. The reduced need for double glazing diminishes the impact of the higher unit costs for double glazing.

While the upgrade strategies employed for developing 7-star rating solutions in the CRIS do bring costs down to a comparable level, this example does raise some significant issues:

- The double-glazing units cost rates assumed by the RIS may not be available to all builders immediately, particularly in the Sydney area where they are less common,
- Some volume manufacturers have significantly higher performance window frames, and it will take a while for other manufacturers to offer more competitive products,
- Builders with supply contracts may not be able to access higher-performance windows at a lower cost until the contract ends, and
- House designs that use window areas that are much larger than the average found in the portal will experience higher costs than modelled by the CRIS if they choose to maintain these window areas. This issue is examined in Appendix A

5 Builder C house in Perth

5.1 Introduction

Builder C provided eight single storey house designs in Perth and Mandurah. One dwelling was selected, which matched the average NCFA of houses in Perth. Most of the dwellings provided were smaller than the average. The dwelling assessed had most living room windows arranged along one side of the building. It, therefore, has a strong sensitivity to orientation. To determine the impact of orientation on upgrade costs, 7-star upgrades were tested on three orientations: best, average, and worst.

5.2 Upgrades needed to achieve 7-stars

A seven star solution was not provided by Builder C. The following modifications were applied to obtain 7-stars:

1. On the most favourable orientation with the living areas facing north:

- Add 10 mm Expanded Polystyrene (EPS: R-value of 0.26) to the brick cavity walls of the Kitchen/Living/Dining room,
- Change roof colour from Solar Absorptance of 0.32 to 0.42 (see colorbond table below)

Note that wall insulation does not need to be suspended between the leaves of brickwork. It can be pushed against the inner leaf. This ensures that a clear cavity of 40 mm is maintained. Note that a 50 mm cavity is used in brick cavity walls in Perth; it is 40mm in eastern states.

Cost: around $200

2. When living areas face southwest, the house rating is around the average for all orientations.

Upgrades needed when facing southwest:

- Add 10 mm EPS (R0.26) to all brick cavity walls.
- Change roof colour from Solar Absorptance of 0.32 to 0.53 (see colorbond table below)

Cost: around $800

3. Living area faces east

- Add 10 mm EPS (R0.26) to all brick cavity walls.
- Change roof colour from Solar Absorptance of 0.32 to 0.53 (see colorbond table below)
- Add 3 x 1400 mm ceiling fans to the Kitchen/Living/Dining room

Even in the worst case, the upgrade cost is only around $1,300. This cost is slightly higher than the average cost in Perth, but other orientations are substantially cheaper.

Cost: around $1600

Table 7 Colorbond Solar Absorptance values used

Solar Absorptance	Colorbond colour
0.23	Whitehaven®
0.32	Classic Cream™
0.42	Paperbark®
0.53	Conservatory®
0.64	Wallaby™
0.73	Monument®
0.96	Nightsky®

5.3 Insulating Brick Cavity walls

10 mm polystyrene boards are a cheap alternative for insulating brick cavity construction. See https://www.jamesbuildingsupplies.com.au/polystyrene-sheets/. These polystyrene sheets retail for $2.13 / m^2. The CRIS assumes an installed cost of close to $5.00 per m^2. This represents a substantially lower material cost than for products that need to be suspended between the brick leaves to create two air spaces (which often cost more than $10/m^2). Labour costs will also be lower.

There has been substantial resistance to installing insulation in Brick Cavity walls in Perth. This resistance may have been due to the high material cost and 'fiddly' installation of those products which have been extensively marketed for this purpose. This report has found that to achieve 7-stars in Perth, only minimal amounts of insulation are needed, and the heavily marketed alternatives provide significantly higher R-values. It may seem counter-intuitive that R values as low as 0.26 are all that is required to achieve 7-stars. However, there are two reasons why this is the case:

- Firstly, the law of diminishing returns for insulation. The first increment of R-value will always be more effective than subsequent increments, and
- Secondly, the insulation helps break the link between the inner leaf and the external temperatures the outer leaf is exposed to. This allows the inner leaf to react more as internal mass than an external wall linked to the outside temperature.

5.4 Conclusion

On average, the costs for this house will be slightly lower than the CRIS cost. Evaluating this example supports the CRIS central case in Perth.

6 Appendix A Large Window areas

The industry has expressed concern over the consultation period that the costs modelled by CRIS are too low because the CRIS modelled dwellings with only slightly higher window areas than average and trimmed window areas in optimising ratings from 6 to 7-stars.

One of the dwellings submitted by the industry had significantly larger windows than the average (by around 27%) for its climate zone. While it was possible to achieve 7-stars at costs consistent with the CRIS with this house by trimming window areas, the ABCB decided to look at the issue of the impact of window size on compliance costs in greater detail. To assist with this task, CSIRO provided more detailed information on the frequency distribution of the size of windows in the field was than is available from the public versions of the NatHERS portal.

The following information is presented in subsequent sections to compare the window areas from the portal and the houses rated for the CRIS. The average window ratio are presented for three cases:

- The average window ratio from the portal, which includes all Class 1 housing,
- The average window ratio for the detached volume houses from the CRIS, and
- The average window ratio for all dwellings modelled for the CRIS, including attached and climatically adapted dwellings.

The results are shown for 6-stars and 7-stars. Outside capital cities, the numbers of dwellings at 7-stars are low, so these statistics may not be as reliable as those in Capital cities.

It is understood that dwellings that voluntarily exceed minimum requirements at 7-stars may not reflect the same design strategies used to achieve 7-stars as a mandatory requirement. Consequently, it is not clear that the market response to a 7-star minimum requirement will be as described in the portal as a whole.

In addition to the average window ratios, the proportion of dwellings with window to floor area ratios greater than or equal to 0.25, 0.30 and 0.35 are shown. These proportions will help identify that part of the market that may experience higher costs because they have chosen to use larger window areas.

6.1 Window to floor area ratios at 6-stars

Table 8 shows the window ratios of all dwellings rated in the portal at 6-stars compared with the average window ratios used for the CRIS and the proportion of dwellings in the portal with higher-than-average window ratios.

Figures in blue highlight show window ratios modelled in the CRIS were lower than those from the portal.

Table 8 Window area characteristics of 6-star housing from the portal and as simulated for the CRIS

NatHERS Climate Zone	Average Window Ratio at 6-stars			Portal Proportion with higher window area		
	Portal	CRIS SBH01-06	CRIS All Houses	0.25 or more	0.30 or more	0.35 or more
1 Darwin	0.208	0.233	0.251	19.7%	4.6%	1.2%
3 Longreach	0.199	0.234	0.264	17.7%	0.0%	0.0%
10 Brisbane	0.218	0.242	0.262	27.1%	8.5%	3.1%
13 Perth	0.228	0.230	0.268	34.7%	9.3%	2.8%
16 Adelaide	0.217	0.232	0.271	24.7%	6.7%	2.2%
24 Canberra	0.248	0.234	0.269	46.4%	22.5%	10.5%
26 Hobart	0.279	0.234	0.266	65.0%	33.9%	16.8%
27 Mildura	0.199	0.238	0.266	13.7%	4.1%	1.3%
28 West Sydney	0.209	0.230	0.262	20.4%	4.4%	1.0%
32 Cairns	0.252	0.236	0.264	49.2%	19.9%	9.0%
60 Tullamarine	0.224	0.233	0.278	30.7%	10.4%	4.5%
69 Thredbo	0.259	0.246	0.287	52.7%	25.6%	18.5%

Table 8 shows that the window ratio of 6-star houses assessed by the CRIS is 18% higher than the ratios reported in the portal. The window ratios for the volume detached houses are 4.3% higher. In some climates, particularly for the volume detached houses, the ratios are slightly lower than reported in the portal.

6.2 Discussion

6.2.1 Climates with high window sizes at 6-stars

Where a climate zone had more than 25% of ratings above a Window size of 25% or more further examination of the portal data was undertaken to understand what may have contributed to these higher window areas. This section also discusses whether the incidence of higher window areas may have affected the central case in the CRIS. It is important to model larger window sizes in these climates to ensure that the potentially higher costs for some market segments are captured.

Hobart and Canberra (26 and 24)

Dwellings modelled for the CRIS in Hobart (CZ26) have a slightly lower average window size than shown in the portal. Both Canberra (CZ24) and Hobart have a higher proportion of windows above 30% window ratio than the average at 6-stars. Further investigation of the portal data shows that, in both climates, houses in these locations have a significantly higher area of north windows and more extensive use of double glazing than in other climate zones. These characteristics allow larger glazing areas to be used.

In these climates, the market is already choosing design strategies at 6-stars to facilitate the use of larger glazing areas. Therefore, it is essential to check whether dwellings with larger window areas experience higher costs in these climates.

In Hobart, the average floor area is significantly lower than in other climate zones: 115 m^2 compared to a national average of 147m^2. Smaller houses usually have a larger window to floor area ratio and do not need to meet as stringent requirements as large houses due to the area correction. The smaller houses assessed by the CRIS had an average window ratio of 28.2% at 6-stars, which is higher than the portal average for Hobart (27.9%).

Cairns (32)

In Cairns (CZ32), window areas at 6-stars in the portal are slightly larger than the average for the volume detached dwellings. Across all of the houses modelled, the CRIS window areas are higher. Houses SBH07 and SBH19 from the CRIS are well oriented, highly ventilated dwellings with a window ratio of around 0.39 at 6-stars, i.e. 65% higher than the volume houses. It may be that elements of good tropical design are more prevalent in Cairns, and this is how higher window ratios are achieved. Note that 7-star upgrade costs for SBH07 and SBH19 were \$1.70/m^2 below the cost of the volume houses, despite their much larger window areas.

Thredbo (69)

There were only 182 6-star houses in the Thredbo sample, so the results observed may not be statistically significant but may represent the properties of specific developments. Note that window areas at 6-stars for the CRIS houses were well above the average: 28.7% compared to the portal average of 25.9%. This average window size was the highest used in any climate zone, so the CRIS analysis does reflect the general trend in Alpine areas.

Tullamarine (60)

30.7% of houses in the portal in this climate have a window size over a 0.25 window ratio. The average window ratio for dwellings in this climate modelled in the CRIS was well above the average: 0.278 compared to 0.224, so the higher areas found in the portal are reflected in the average sizes.

Perth (13)

The average Window ratio for 6-star houses from the portal in Perth was 0.228, while the average from the CRIS houses was 0.268. Perth shows a high proportion of dwellings with a window ratio of over 0.25 (35%), so the window areas assumed in the CRIS reflect the higher window ratios.

There may be some reasons why houses in Perth have a greater proportion of higher Window ratios than other climates:

- In Perth, the use of high thermal mass external and internal brick cavity walls may be facilitating the use of higher window areas, particularly when the orientation of windows is more favourable.
- The use of insulation in Brick cavity walls is generally avoided in Perth; however, the addition of just 10mm of polystyrene to brick cavity walls often adds more than one-star to the rating and would facilitate the use of higher window areas.

Unfortunately, it was not possible to obtain further portal data to examine these issues.

6.3 Window to floor area ratios at 7-stars

Table 9 shows the window sizes of all dwellings rated in the portal at 7-stars compared with the sample used for the CRIS and the proportion of dwellings in the portal with higher-than-average window to NCFA ratios.

Figures in blue highlight show window ratios modelled in the CRIS were lower than those from the portal.

Table 9 Window area characteristics of 7-star housing from the portal and as simulated for the CRIS

Climate Zone	Average Window Ratio 7 stars			Portal Proportion higher window area		
	Portal	CRIS SBH01-06	CRIS All Houses	Ratio of 0.25 or more	Ratio of 0.30 or more	Ratio of 0.35 or more
1 Darwin	0.152	0.216	0.223	13.4%	3.0%	0.0%
3 Longreach	0.190	0.227	0.254	16.7%	8.3%	0.0%
10 Brisbane	0.202	0.232	0.254	16.2%	4.7%	1.6%
13 Perth	0.227	0.215	0.251	36.0%	17.7%	4.1%
16 Adelaide	0.179	0.217	0.251	9.3%	4.1%	2.6%
24 Canberra	0.216	0.218	0.250	26.4%	11.9%	7.4%
26 Hobart	0.233	0.221	0.249	39.5%	11.3%	4.4%
27 Mildura	0.183	0.217	0.246	10.4%	3.7%	1.2%
28 West Sydney	0.182	0.218	0.247	9.6%	2.8%	0.7%
32 Cairns	0.228	0.227	0.253	33.9%	14.2%	6.2%
60 Tullamarine	0.223	0.216	0.250	36.7%	20.0%	3.3%
69 Thredbo	0.211	0.223	0.257	38.5%	15.4%	7.7%

Table 9 shows that, on average, the window to NCFA ratio of 7-star houses assessed by the CRIS is 25% higher than the ratios reported in the portal. The ratios for just the volume detached houses are an average of 11% higher. Using larger window areas than shown in the portal for 7-stars was a deliberate decision because houses with smaller window areas would have lower upgrade costs.

As with 6-star window area statistics, in some climates, particularly for the volume detached houses, the ratios are lower than reported in the portal, but the difference is slight.

6.4 Selection of a window ratio for cost evaluation

6.4.1 Window areas are likely to be smaller at 7-stars than 6-stars

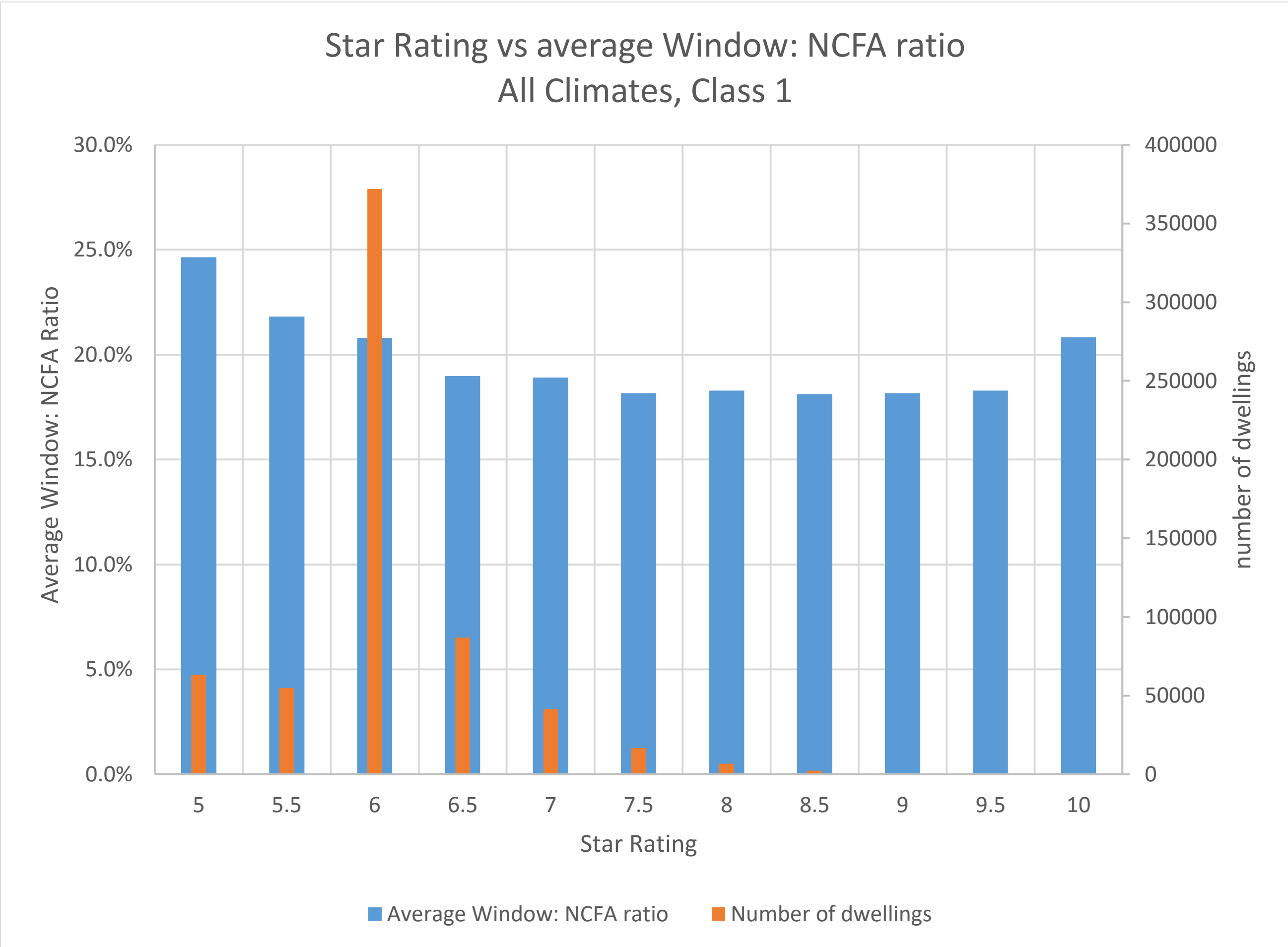
The portal data shows that, across all climates, the average window size decreases as the star rating increases, particularly between 5 and 7.5 stars. Figure 3 shows this data. This trend is observed in all the climate zones modelled for the CRIS. This trend is not observed in 14 of the 69 NatHERS zones, but the construction volume in these climates is only 9% of the total Class 1 dwellings in the portal. Given this trend, it is considered highly likely that some reduction in window area would be applied in the field.

Across all climates, the window size at 7-stars is 10% smaller than at 6-stars in the portal data.

Because the market response to a voluntary 7-stars may be different from mandatory 7-stars, only around half this window reduction was applied in the modelling for the CRIS.

Further, the window reduction used in the CRIS was higher in dwellings with large window areas with a greater scope for window reduction without sacrificing the look and feel of the house design. Consequently, there was no window size reduction in some dwellings with smaller window ratios.

Figure 3 Average window size by star rating for all climates and number of dwellings



Even though a window area reduction at 7-stars is likely, some market segments may not choose to do this. Further, if those sections of the market that do not reduce window size have large window areas, the costs may be significantly greater than predicted by the modelling for the CRIS. Therefore, it is important to discuss the costs that these sections of the market may incur. The following section describes how the window ratio used to examine these effects was selected.

6.4.2 Selecting the appropriate window size

As shown in sections 6.1 and 6.3, the window areas used in the CRIS already exceed the averages shown in the portal. The CRIS window size exceeds the portal average by 18% in all but one climate at 6-stars and 25% for all climates at 7-stars. Window sizes that are well above the average used for the CRIS (25.6% at 6-stars) should be used to evaluate the costs for houses with larger dwellings. The data from the portal was only provided in 5% increments, so the options available at larger sizes are effectively only 30% and 35%. Larger sized windows than 35% have too low a market penetration to be significant (see Table 10 column 2).

Sections 6.1 and 6.3 showed the proportion of houses with window ratios exceeding certain levels for each NatHERS Climate Zones. The CRIS allocates the costs and savings for these 12 representative climate zones to other similar climate zones. Table 10 shows the window area proportions and annual construction volume allocated to all similar climates for the CRIS.

To estimate the proportion of the market that will construct houses with higher window areas will involve a prediction of how the market will adapt to the higher stringency. Any prediction of market behaviour in response to 7-stars will necessarily be arbitrary. Some parts of the industry will reduce window areas in response to 7-stars, and some will not. In the absence of any better information, the estimated market response was calculated by taking the average of 6-star and 7-star higher window areas. This information is shown in Table 10 below, together with the annual construction volume assumed for all climates allocated to the representative climate.

Table 10 Proportion of dwellings with high Window ratios in climates assessed for the CRIS

NatHERS Climate Zone	Average penetration of 6 and 7-star dwellings with Window ratio of		Annual Class 1 volume allocated to CZ in CRIS	NCC Climate
	0.35 or higher	0.30 or higher		
1 Darwin	0.6%	4.3%	934	1
3 Longreach	0.0%	3.2%	322	3
10 Brisbane	2.4%	7.2%	27,894	2
13 Perth	3.5%	15.8%	13,260	5
16 Adelaide	2.4%	5.4%	8,276	5
24 Canberra	9.0%	10.2%	9,536	7
26 Hobart	10.6%	20.4%	2,818	7
27 Mildura	1.2%	3.8%	4,779	4
28 West Sydney	0.9%	6.8%	14,163	5
32 Cairns	7.6%	11.0%	3,375	1
60 Tullamarine	3.9%	8.0%	62,565	6
69 Thredbo	13.1%	34.0%	96	8

The proportion of Class 1 dwellings with higher window areas vary significantly between climate zones (as discussed in sections 6.1 and 6.2). The construction volume-weighted average proportion above a Window ratio of 0.3 or above is 8.6% and 3.6% for 0.35 or above. Given that such a low percentage of the national market would be affected by the selection of 0.35, the window area chosen is a Window ratio of 0.3.

6.5 Case Studies for Class 1 dwellings with large window areas

A window size schedule was developed for the 0.30 window ratio. This schedule is shown in Table 11. Costs were calculated for upgrading from 6-stars to 7-stars without changing window sizes.

There is considerably more freedom to reduce window areas at such high window sizes without significantly sacrificing amenity. Consequently, a further window schedule was developed to evaluate the benefits of trimming windows at this higher window area size. The reduced window size schedule provides a larger average window size than the CRIS modelled at 7-stars. In addition to showing the benefits of reducing window size, the addition of a second data point allows the extent of window size reduction that would produce the same cost as found by the CRIS. This second window schedule is also shown in Table 11.

The second window schedule seeks to reduce window areas evenly across all zones. Changes to window sizes are shown in a bold and **orange** font. A more targeted reduction focussing on rooms with the highest heating and cooling loads would be more cost-effective. Because the rooms with the highest load change across climate zones, a more targeted approach was not taken. At a 0.30 Window ratio, both the 6-star and 7-star upgrade costs will increase. The costs reported below show the upgrade cost from 6-stars to 7-stars only.

Table 11 Window schedules for larger size windows

Window ratio :	0.30		0.26	
Zone	Height	Width	Height	Width
Entry	2100	232	2100	232
Study	2100	900	**1800**	900
Study	2100	900	**1800**	900
Living 1/Hall	2100	1800	2100	1800
Kitchen Meals Family	2100	2700	2100	**2400**
Kitchen Meals Family	2100	2700	2100	**2400**
Kitchen Meals Family	2100	1500	**1500**	1500
Kitchen Meals Family	2100	1500	**1500**	1500
Games	2100	2400	2100	**2100**
Games	2100	900	2100	900
Games	2100	2100	2100	2100
Laundry	2100	1500	2100	1500
Bed1/Walk in Robe 1	514	2400	514	**2100**
Bed1/Walk in Robe 1	2100	2700	2100	**2100**
Bed1/Walk in Robe 1	2100	600	2100	600
Ensuite	2100	1200	2100	1200
Ensuite WC	2100	600	2100	600
Bath	2100	1800	2100	1800
Bed 2/ Walk in Robe 2	1400	2400	1400	**2100**
Bed3/ Walk in Robe 3	1500	2700	1500	**2100**
Bed4/ Walk in Robe 4	2100	2400	2100	**2100**
Living 2	2100	2400	2100	**2100**
Living 2	1500	2410	1500	**1800**

6.6 Costs to upgrade from 6- to 7-stars with higher window areas

Table 12 shows upgrade costs in each climate zone for:

- The proportion of dwellings assumed to have a window ratio of 0.3 or over,
- The original upgrade cost assumed by the CRIS,
- The upgrade cost for a 0.30 Window ratio at 6- and 7-stars,
- The upgrade cost for a 0.30 window ratio at 6-stars and a 26.5% ratio at 7-stars, and
- The window ratio at 7-stars that produces the same cost as the CRIS (break-even window ratio).

Table 12 Upgrade costs for all climate zones evaluated with a 0.30 window ratio at 6-stars

NatHERS Climate Zone	Assumed penetration of dwellings with a window ratio of 0.3 or higher	CRIS Cost	Cost at 0.30	Cost at 0.26	Break-even Window ratio*
1 Darwin	4.3%	$1,101.69	$5,789.60	-$243.25	0.272
3 Longreach	3.2%	$688.98	$3,192.65	-$450.53	0.274
10 Brisbane	7.2%	$639.64	$2,395.16	$265.86	0.270
13 Perth	15.8%	$1,497.48	$2,217.15	$926.85	0.279
16 Adelaide	5.4%	$2,360.24	$6,924.06	$2,386.98	0.264
24 Canberra	10.2%	$3,823.70	$8,804.06	$4,631.97	0.256
26 Hobart	20.4%	$4,519.61	$5,061.55	$3,012.03	0.290
27 Mildura	3.8%	$3,122.12	$9,592.28	$1,341.17	0.271
28 West Sydney	6.8%	$2,443.45	$5,903.35	$544.90	0.276
32 Cairns	11.0%	$1,000.15	$2,438.08	$409.48	0.274
60 Tullamarine	8.0%	$3,728.31	$5,834.83	$998.42	0.283
69 Thredbo	34.0%	$1,323.13	$5,556.13	-$487.60	0.274

* The “Break even window ratio” is the window ratio where the upgrade costs will be the same as the original case in the CRIS.

Table 12 shows 7-star upgrade costs increase between $500 and $6,600 if a window ratio of 0.3 is maintained at both 6- and 7- stars. A substantial reduction in compliance costs can be achieved in all climate zones by reducing the window ratio to 0.265. In all climate zones except Canberra, the compliance cost at 0.265 window ratio are substantially lower than the CRIS reported costs. Costs would be maintained at the CRIS predicted level with an average window ratio of 0.274. This window size is still 20% higher than the average window ratio in the portal for 6-star dwellings and 35% higher than the ratio for 7-star dwellings.

The substantial reduction in upgrade costs achieved by a 9% reduction in window ratios to 0.274 shows that there will be significant pressure to reduce window areas in highly glazed homes in order to maintain a competitive advantage.

The costs in Table 12give an indication of how the BCR would be affected if builders of highly glazed homes choose to maintain these high glazing areas. However, because the costs were estimated for the largest of the CRIS sample, this additional cost is likely to be an over estimate on average due to the impact of the NatHERS area correction on larger dwellings.

7 Appendix B: Upgrades required for 7-stars with 0.3 window ratios in each climate zone

The flowing sections describe the upgrade needed to improve the star rating from 6-7stars with a window ratio of 0.30. The cost of achieving 6-stars is much higher than the original base case, so the additional costs for the houses at the higher window ratio may seem a little low. In addition, the window ratio where the cost of improvements become the same as the cost quote in the CRIS is also shown. This ratio varies depending on the climate zone.

7.1 Darwin (NatHERS Climate 1)

Original Cost for SBH01 with a Window ratio of 0.206 at 6-stars and 0.195 at 7-stars: $1,101.69

Cost of upgrading with a ratio of 0.30 at 6- and 7-stars: $5,789.60, i.e. 426% higher.

- Note that the 6-star version needed 26.3m^2 of low-e coated louvre glazing to achieve 6-stars (compared to 14.4 m^2 of non coated louvre glazing with the original lower window area); the 7-star version required 32.6 m^2 of low e coated louvre glazing.
- At 7-stars, other upgrades included
  - Replaced 32.6 square metres of single clear glazing with low-e coated, tinted glazing.

However, if window ratio was trimmed from 0.30 to 26.3% at 7-stars (still 27% larger than the original 6-stars), the cost is only -$243.25. Single low e coated tinted glazing can be reduced by 16 m^2, and louvre glazing by 15m^2. The original cost can be maintained if the window ratio is reduced to 0.272.

7.2 Longreach (NatHERS Climate 3)

Original Cost for SBH01 with a window ratio of 0.206 at 6-stars and 0.195 at 7-stars: $688.98

Cost of upgrading with a ratio of 0.30 at 6- and 7-stars: $3,192.65, i.e. 363% higher.

- Note that the 6-star version required 43.7m2 of low-e coated tinted single glazing and 6-stars (compared to 26.1 m^2 with the original lower window area); the 7-star version required 56.8 m^2 of low e coated tinted single glazing.
- At 7-stars, other upgrades included
  - Convert 8 x 1200 diameter ceiling fans to 1400 diameter and add a further 3 x 1400 mm diameter fans (13 fans in total),
  - Add R1.0 insulation to the external east and west walls of the Kitchen/Meals and Games rooms (60m^2).

However, if window ratio was trimmed from 0.30 to 0.26 at 7-stars (still 27% larger than the original 6-stars), the cost is only -$450.53. Wall insulation could be eliminated at the lower window ratio. The original cost can be maintained if the window ratio is reduced to 0.274.

7.3 Brisbane (NatHERS Climate 10)

Original Cost for SBH01 with a Window ratio of 0.207 at 6-stars and 0.191 at 7-stars: $639.64

Cost of upgrading with a ratio of 0.299 at 6- and 7-stars: $2,395.16, i.e. 274% higher.

- Note that the 6-star version needed 26.3m2 of single low e to achieve 6-stars (compared to the original no single low e with the original lower window area); the 7-star version required 43.3 m2 of single low e.
- At 7-stars, other upgrades included
    - upgraded the roof insulation from R3 to R5,
    - increased the number of 1400 mm diameter from 4 to 9, reduced the number of 1200 diameter ceiling fans from 6 to 4,
    - replaced 32 m^2 carpeted floor with a tiled floor to engage the slab's thermal mass (a reasonably significant impact)
    - used a light coloured roof and light coloured window frames

However, if window area was trimmed from 29.9% to 26.3% at 7-stars (still 27% larger than the original 6-stars), the cost is only $265.86. Single low-e glazing is reduced to 25.5 m^2. The original cost can be maintained if the window ratio is reduced to 0.270.

7.4 Perth (NatHERS climate 13)

Original Cost for SBH01 with a Window ratio of 0.209 at 6-stars and 0.190 at 7-stars: $1,497.48

Cost of upgrading with a ratio of 0.299 at 6 and 7-stars: $2,217.15, i.e. 48% higher.

- At 7-stars, upgrades included
    - added 29 m^2 of single low-e glalzing,
    - added 55 m^2 of tiled floor.

However, if you did trim the window area from 0.299 to 0.263 at 7-stars (still 27% larger than the original), the cost is only $926.85. The area of single low-e coated glazing can be reduced to 10 m^2 at this window ratio. The original cost can be maintained if the window ratio is reduced to 0.279.

7.5 Adelaide (NatHERS climate 16)

Original Cost for SBH01 with a Window ratio of 0.206 at 6-stars and 0.187 at 7-stars: $2,360.24

Cost of upgrading with a ratio of 0.299 at 6 and 7-stars: $6,924.06, i.e. 193% higher.

- Note that the 6-star version needed 39.5 m2 of double glazing to achieve 6-stars (compared to the original 24.9 m2 with the initial lower window area); the 7-star version required 53.4 m2.
- At 7-stars, other upgrades included
    - upgraded the roof insulation from R5 to R6, and wall insulation from R2.5 to 2.7,
    - added 12 m^2 of external blinds (to the existing 5m^2),
    - replaced the timber floating floor with a tiled floor to engage the slab's thermal mass better,

However, if window area was trimmed from 29.9% to 26.3% at 7-stars (still 27% larger than the original), the cost is only $2,386.98. All external blinds can be eliminated (17 m^2).

7.6 Canberra (NatHERS Climate 24)

Original Cost for SBH01 with a Window ratio of 0.206 at 6-stars and 0.181 at 7-stars: $3,823.70

Cost of upgrading with a ratio of 0.299 at 6- and 7-stars: $8,804.06, i.e. 130% higher.

- Note that the 6-star version needed 27.7m^2 of double glazing to achieve 6-stars (compared to the original no single low e with the original lower window area); the 7-star version required 53.4 m^2 of double glazing.
- At 7-stars, other upgrades included
  - upgraded the roof insulation from R5 to R6,
  - upgraded the wall insulation from R2.5 to R2.7,
  - replaced 82 m^2 carpeted floor with a tiled floor to engage the slab's thermal mass (a reasonably significant impact)
  - used a light coloured roof and light coloured window frames

However, if window area was trimmed from 29.9% to 26.3% at 7-stars (still 27% larger than the original 6-stars), the cost is only $4,631.97. Still higher than the original cost but only by 21%. The original cost can be maintained if the window ratio is reduced to 25.6%.

7.7 Hobart (NatHERS climate 26)

Original Cost for SBH01 with a Window ratio of 0.206 at 6-stars and 0.187 at 7-stars: $3,823.70

Cost of upgrading with a ratio of 0.299 at 6 and 7-stars: $5,061.55, i.e. 12% higher.

- Note that the 6-star version needed 27.7m^2 of double glazing to achieve 6-stars (compared to the original 18.0 m^2 with the initial lower window area); the 7-star version required 53.4 m^2.
- At 7-stars, other upgrades included
  - upgraded the roof insulation from R5 to R6,
  - Increase wall insulation from R2.5 to R2.7,
  - replace the timber floating floor with a tiled floor to engage the slab's thermal mass better, 82 m^2.
  - use a darker window frame colour to reduce heat loss through the frame (it absorbs more heat during the day).

However, if window area was trimmed from 29.9% to 26.3% at 7-stars (still 27% larger than the original) reduces the cost by $$2,049.52. This allows the elimination of 26m^2 of double glazing and lowering the ceiling R to 5.0. The original cost could be maintained at the original level in the CRIS if the window ratio was reduced to 0.256.

7.8 Mildura (NatHERS climate 27)

Original Cost for SBH01 with a Window ratio of 0.206 at 6-stars and 19.0% at 7-stars: $3,122.12

Cost of upgrading with a ratio of 0.299 at 6 and 7-stars: $9,592.28, i.e. 207% higher.

- Note that the 6-star version needed 41.4 m^2 of double glazing to achieve 6-stars (compared to the original 28.6 m2 with the initial lower window area); the 7-star version required 53.4 m2.
- At 7-stars, other upgrades included
  - upgraded the roof insulation from R5 to R6, and increased wall insulation from R2.5 to R2.7
  - the cooling was much higher in two large rooms due to the greater heat gain through larger windows, so I added five ceiling fans,
  - replaced the timber floating floor with a tiled floor to engage the slab's thermal mass better,
  - added 17 m^2 of external blinds.

However, if window area was trimmed from 29.9% to 26.3% at 7-stars (still 27% larger than the original), the cost is only $1,341.17. Due to the lower heat gain through the smaller windows, external blinds and ceiling fans can be eliminated. The original cost can be maintained if the window ratio is reduced to 0.271.

7.9 Sydney (West Sydney, NatHERS Climate 28)

Original Cost for SBH01 with a Window ratio of 0.206 at 6-stars and 0.187 at 7-stars: $2,443.45

Cost of upgrading with a ratio of 0.299 at 6- and 7-stars: $5,903.35, i.e. 142% higher.

- Note that the 6-star version needed 42.7m^2 of single low e and 5.7 m^2 of double glazing to achieve 6-stars (compared to the original 5.3 m^2 of double glazing and no single low e with the original lower window area); the 7-star version required 19.5 m^2 of single low e and 25.7 m^2 of double glazing.
- At 7-stars, other upgrades included
  - upgraded the roof insulation from R5 to R6,
  - added two ceiling fans to the existing 6,
  - replaced 42 m^2 carpeted floor with a tiled floor to engage the slab's thermal mass (a reasonably significant impact)
  - added 10.7 m2 of external blinds (2 windows) to large east and west windows in the rooms with the highest cooling loads

However, if window area was trimmed from 29.9% to 26.3% at 7-stars (still 27% larger than the original 6-stars), the cost is only $544.90. The external blinds can be eliminated. Double glazing is reduced to 9.5 m^2, but single low e goes up to 30m^2. The original cost can be maintained if the window ratio is reduced to 0.276.

7.10 Cairns (NatHERS Climate 32)

Original Cost for SBH01 with a Window ratio of 0.206 at 6-stars and 0.195 at 7-stars: $1,000.15

Cost of upgrading with a ratio of 0.299 at 6- and 7-stars: $2,438.08, i.e. 144% higher.

- Note that the 6-star version needed 26.3m^2 of low-e coated tinted single glazing to achieve 6-stars (compared to 4 m^2 and a further 9m^2 of tinted glazing with the original lower window area); the 7-star version required 32.2 m^2 of low e coated tinted single glazing.
- At 7-stars, other upgrades included
  - Convert 8 x 1200 diameter ceiling fans to 1400 diameter and add a further 3 x 1400 mm diameter fans (13 fans in total).
  - Add a further 32 m^2 of tiled floor to the ground floor.

However, if window area was trimmed from 29.9% to 26.3% at 7-stars (still 27% larger than the original 6-stars), the cost is only $409.48. Single low e coated tinted glazing can be reduced by 17 m^2. The original cost can be maintained if the window ratio is reduced to 0.274.

7.11 Melbourne (Tullamarine, NatHERS climate 60)

Original Cost for SBH01 with a Window ratio of 20.6% at 6-stars and 18.7% at 7-stars: $3,728.31

Cost of upgrading with a ratio of 0.299 at 6- and 7-stars: $5,834.83, i.e. 57% higher.

- Note that the 6-star version needed 38.7m2 of double glazing to achieve 6-stars (compared to the original 7.3 m2 with the initial lower window area); the 7-star version required 50.1 m2.
- At 7-stars, other upgrades included
  - upgraded the roof insulation from R4 to R6,
  - the cooling was much higher in three rooms due to the greater heat gain through larger windows, so I added six ceiling fans,
  - replaced the timber floating floor with a tiled floor to engage the slab's thermal mass better, (it wasn't a huge impact)
  - used a darker window frame colour to reduce heat loss through the frame (it absorbs more heat during the day).

However, if window area was trimmed from 29.9% to 26.3% at 7-stars (still 27% larger than the original), the cost is only $998.42. You can reduce ceiling R to 5.0 and delete 3 of the ceiling fans. The original cost can be maintained if the window ratio is reduced to 0.283.

7.12 Thredbo (NatHERS climate 69)

Original Cost for SBH01 with a Window ratio of 0.235 at 6-stars and 0.192 at 7-stars: $1,323.13

Cost of upgrading with a ratio of 0.299 at 6- and 7-stars: $5,556.13, i.e. 320% higher.

- Note that the 6-star version needed 45.3m2 of double glazing to achieve 6-stars (compared to the original 30.3 m2 with the initial lower window area); the 7-star version required 53.4 m2.
- At 7-stars, other upgrades included
  - increasing the roof insulation from R5 to R6 and increasing wall insulation from R2.5 to R2.7
  - changed the colours of walls, roof and window frames from medium to dark,
  - replaced the timber floating floor with a tiled floor to engage the slab's thermal mass better,
  - used a darker window frame colour to reduce heat loss through the frame (it absorbs more heat during the day).

However, if window area was trimmed from 29.9% to 26.3% at 7-stars (still 27% larger than the original), the cost is only -$487.60. Double glazing can be reduced by 14m2, and the insulation levels in walls and ceiling restored to their original values. The original cost can be maintained if the window ratio is reduced to 0.274.

8 Appendix C: The impact of reducing window sizes as part of the improvement from 6 to 7 stars

8.1 Introduction

Feedback from the building industry received during the consultation period revealed concern that the dwellings used for the CRIS had small window areas, and those window areas were reduced when upgrading from 6- to 7-stars. The industry's concern was that costing upgrades to dwellings with small window areas and further reducing these window areas at 7-stars would artificially lower the cost of compliance.

Section 6 showed that the window areas used to develop building fabric costs for the CRIS are significantly larger at both 6- and 7-stars than the averages found in the portal:

- Table 8 showed that the average window size of houses assessed for the CRIS is 18% higher than the portal average, and
- Table 9 showed that the average window size of houses assessed for the CRIS is 25% higher than the portal average.

The dwellings assessed for the CRIS represent houses with higher than average window areas.

In response to the industry's concern over the use of smaller windows at 7-stars, the following sections explain the rationale behind the window reductions used, and evaluates the additional costs for the dwellings used in the CRIS had windows areas not been reduced at 7-stars.

8.2 The rationale for window area reductions

8.2.1 How NatHERS 7-stars affects window size

NatHERS based tools[2] show that window orientation significantly impacts the heating and cooling energy loads required to maintain comfort in a dwelling. Some window orientations will provide lower energy loads than others. Consequently, dwellings with more favourable window orientations can have significantly larger window areas than dwellings with less favourable window orientations. Good window orientation also allows lower 7-star compliance costs.

The six typical dwellings used for assessing building fabric costs were deliberately placed on a poor orientation with the front door facing north. This poor orientation was selected to ensure that compliance costs were not underestimated. Two additional dwellings with climatically adapted design, where most windows had a favourable orientation, were also assessed. Although these dwellings were not included in the CRIS building fabric cost, they provide case studies of how climatically adapted design can allow significantly larger window areas and lower compliance costs.

Table 13 below shows that the average window area that can be achieved with climatically adapted dwellings is typically 50% larger than poorly oriented houses. Compliance costs are also 20-60% lower, even with the larger glazing.

[2] NatHERS runs a full hourly simulation for 12 months of representative weather data. It includes the impact of thermal mass and predicts the airflow through dwellings and its effect on comfort. The solar radiation intensity is calculated for every external surface allowing for its orientation, the position of the sun and the shading impact of wing walls, external obstructions and horizontal overhangs. The NatHERS calculation engine developed by CSIRO, known as Chenath, was tested using the ASHRAE BESTEST procedure when second-generation NatHERS was developed. Its predictions of heat flow, energy load, and internal temperature fell within the range of the world's best thermal performance simulation engines.

Table 13 Impact of good window orientation on compliance cost and window size at 7-stars in various climates

Climate	CRIS Houses		Climatically Adapted	
Darwin	$11.42	21.6%	$4.28	33.3%
Longreach	$8.76	22.7%	$3.65	32.8%
Brisbane	$4.95	23.2%	$2.22	35.5%
Perth	$6.53	21.5%	$5.31	34.4%
Adelaide	$11.41	21.7%	$4.80	33.3%
Canberra	$15.30	21.8%	$9.54	32.8%
Hobart	$11.66	22.1%	$6.81	30.6%
Mildura	$9.88	21.7%	$5.41	30.9%
West Sydney	$10.29	21.8%	$8.14	31.9%
Cairns	$4.71	22.7%	$3.04	33.2%
Tullamarine	$11.86	21.6%	$10.30	32.3%
Thredbo	$10.55	22.3%	$6.81	33.8%

While window area reductions were made to achieve 7-stars, this does not mean that NatHERS will require every house to reduce window area to contain costs or that all homes will need to have small windows to pass 7-stars. The CRIS simply demonstrates that trimming window areas is a cost-effective strategy when orientation is poor. Better house that adapts the design to the lot's orientation offers the potential to allow cheaper compliance and a larger window area.

8.2.2 The basis for window area reduction at 7-stars

While reducing window area is a cost-effective strategy, this approach would not have been pursued if it was demonstratable that the market does not do this at 7-stars. In fact, the NatHERS portal shows that 7-star houses reduce their window areas by much more than the was applied in the modelling for the CRIS. Table 14 shows that the CRIS used less than half the observed reduction in the window ratio shown in the NatHERS portal.

Table 14 Portal data reduction in window ratio compared to CRIS reduction in window ratio

Climate Zone	Location	Average Window : NCFA Ratio at 6-stars	Average Window : NCFA Ratio 7 stars	Portal data % reduction in window ratio at 7-stars	CRIS reduction in window ratio
1	Darwin	0.208	0.152	26.9%	6.9%
3	Longreach	0.199	0.190	4.5%	2.2%
10	Brisbane	0.218	0.202	7.3%	2.4%
13	Perth	0.228	0.227	0.4%	8.0%
16	Adelaide	0.217	0.179	17.5%	6.5%
24	Canberra	0.248	0.216	12.9%	7.6%
26	Hobart	0.279	0.233	16.5%	4.4%
27	Mildura	0.199	0.183	8.0%	5.4%
28	West Sydney	0.209	0.182	12.9%	4.8%
32	Cairns	0.252	0.228	9.5%	5.0%
60	Tullamarine	0.224	0.223	0.5%	5.4%
69	Thredbo	0.259	0.211	18.5%	9.0%
	Average	**0.228**	**0.202**	**11.3%**	**5.6%**

In Perth and Tullamarine (highlighted in yellow), the dwellings rated for the CRIS used a larger window area reduction than in the portal. Similar climate zones like Mandurah (11.9%) and Moorabbin (15.5%) show a larger window ratio reduction.

The work for the CRIS did not use the whole window area reduction shown in the portal because the portal demonstrates how the market is responding to achieving 7-stars voluntarily rather than as a result of a mandatory requirement. Nevertheless, the trend to lower window areas at higher star ratings is so overwhelming in all climate zones that it is clear that some reduction in window ratio would be applied. Figure 3 shows the average window ratios averaged across all 69 climate zones at various star ratings and demonstrates the strength of this trend.

Lower ratings are allowed in Climate Zone 2 if an Outdoor Living Area (OLA) is used. With an OLA which has a fan installed, a 5-star rating is currently allowed instead of a 6-star rating. Ratings in Climate Zone 2 will therefore show how the market responds to regulatory requirements at different rating levels, albeit at a lower overall rating than is proposed for NCC 2022.

Brisbane has the highest construction volume in NCC Climate Zone 2. Comparing 5, 5.5 and 6-star window ratios will reveal how the Brisbane market reacts to lower star ratings within a regulatory framework.

Table 15 Window Ratio at different star rating levels in Brisbane

Star Rating	Number of dwellings	Average Window Ratio	% reduction compared to 5-stars	% reduction compared to next lowest rating
5	9667	0.258	0.0%	0.0%
5.5	5857	0.239	7.4%	7.4%
6	17747	0.219	15.2%	8.4%
6.5	7581	0.206	20.1%	5.8%
7	5433	0.202	21.8%	2.1%

Table 15 shows that 5- and 5.5-star (an OLA without a ceiling fan) shows a clear trend to lower window ratios as the star rating increases within a regulatory framework.

8.2.3 Conclusion

The previous sections explain the rationale behind the decision to reduce window areas at 7-stars to evaluate building fabric cost impacts at 7-stars for NCC 2022. The decision was based on the information contained in the NatHERS data portal, which showed a clear trend to reduced window ratios at higher star rating levels. Over 40,000 Class 1 7-star dwellings have already been registered in the NatHERS portal across Australia since May 2016 (around 11% of the construction volume of 6-star dwellings). The evidence provided by the NatHERS portal is too significant to be ignored. Nevertheless, to ensure a conservative approach was taken, the reduction in window ratio used to evaluate 7-stars was just under half the average reduction observed in the portal.

8.3 The impact on compliance cost of window area reduction

8.3.1 Additional Costs

The decision to apply window ratio reductions reflects the observed trend in NatHERS ratings. It is a common-sense strategy to contain the impact of higher construction costs in dwellings with poor window orientation. Builders wishing to maintain their competitive position in the market are likely to take the approach described, particularly where the current window areas are high (as described in section 6). However, it may take some time for the building industry to adapt to the 7-star rating. Therefore, it is important to quantify the impacts of the window ratio reduction applied.

Each of the typical houses (SBH01 to SBH06) were re-rated with the window area used to obtain 6-stars. Each dwelling was then optimised to achieve 7-stars with the higher window area, and the costs to achieve 7-stars were derived from the new building specifications. Table 16 shows the average cost per square metre increase required to achieve 7-stars with the higher window area in each climate zone modelled. The table also shows the average window area reduction across all houses and shows the cost increase as a percentage of the average cost/m^2.

Table 16 Impacts of maintaining 6-star window sizes at 7-stars

Climate	CRIS original \$ / m^2	CRIS % reduction in window area	Increase with no window reduction \$/m^2	% increase with no window reduction
Darwin	\$11.42	6.9%	\$1.85	16%
Longreach	\$8.76	2.2%	\$1.29	15%
Brisbane	\$3.50	2.4%	\$1.15	33%
Perth	\$6.53	8.0%	\$1.75	27%
Adelaide	\$11.41	6.5%	\$3.43	30%
Canberra	\$15.30	7.6%	\$3.69	24%
Hobart	\$11.66	4.4%	\$1.50	13%
Mildura	\$9.88	5.4%	\$3.27	33%
West Sydney	\$8.51	4.8%	\$2.21	26%
Cairns	\$4.71	5.0%	\$0.90	19%
Tullamarine	\$8.46	5.4%	\$2.39	28%
Thredbo	\$11.52	9.0%	\$6.68	58%

The cost increase to maintain the size of windows at the 6-star level varies between 13% (Hobart) and 33% (Brisbane and Mildura) in all climate zones except Alpine Areas. This increase represents an additional cost per square metre of between \$0.90 (in Cairns) and \$3.69 (in Canberra).

In a 200 m^2 house, these costs represent an average \$180-\$740 increase in compliance costs per house.

At these costs, some builders may choose to retain the larger window area and maintain their competitive position by lowering the costs of other fixtures, fittings and appliances.

8.3.2 High costs in Alpine Areas

Due to the extremely cold climate, alpine areas are particularly sensitive to window areas. Even with window U-Values as low as 2.2 -2.8 for the double-glazed units, a window will lose heat after sunset at 6- 8 times the rate of the same area of insulated wall. North facing windows can gain more heat than they lose over the day, but because few dwellings contained a significant area of north-facing windows in living areas, windows remained the weak link in this climate. Without reducing window areas in this climate, a much larger area of double glazing must be used. The higher costs without window area reduction will provide a significant impetus for the industry to adopt this design approach.

8.3.3 Conclusion

While the additional costs reported in Table 16 are small, they are significant in aggregate. Given the price sensitivity of the housing market, it is likely that industry would ultimately pursue some level of window trimming to contain costs.

There is evidence that the market does reduce window areas to meet higher rating levels:

- The existing market response observed in over 40,000 7-star dwellings already assessed in the NatHERS portal shows that the market already responds in this way. The RIS only applied half the window area reduction observed in the portal.
- In Brisbane, where a lower rating is allowed through the addition of an Outdoor Living Area, window areas are reduced when faced with higher ratings.

The CRIS houses were subject to window area reductions. However, this does not mean that all dwellings will need to reduce window areas to achieve 7-stars or face higher costs if they do not. The climatically adapted dwellings assessed to provide case study examples of dwelling designs with ideal window orientation used 50% higher window areas and cost between 20% and 60% less to meet a 7-star building fabric standard. Improved design practices to increase the area of well-oriented windows, therefore, offers significantly greater design freedom and lower costs.

As reported in section 3.5, this may not need a change to house design at all in some cases. Flipping the plan to improve window orientation saves between $1,000 and $2,000 in the examples provided by the building industry. Further, small changes to sales practices, so that dwelling designs are matched with the lots where costs are lower also provides a similar potential to reduce costs.

For all these reasons, the costs estimated for the building fabric upgrade under the central case remain robust and representative of average costs of the life of the regulation. To ensure costs are contained industry will need to invest time to adapt to the higher building fabric standard, design and sales practices and retrain.